Quarterly Report
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Abstract

Our major achievements of this quarter were: (1) our first attempt at conducting atmospheric correction (e.g., water vapor absorption and Rayleigh scattering) in MAS remote sensing retrievals, (2) the creation of a comprehensive ER-2 mission summary booklet for the science community, and (3) extensive work done on preparing a MAS instrumentation paper for publication.

I. Task Objectives

With the use of related airborne instrumentation, such as the MODIS Airborne Simulator (MAS) and Cloud Absorption Radiometer (CAR) in intensive field experiments, our primary objective is to extend and expand algorithms for retrieving the optical thickness and effective radius of clouds from radiation measurements to be obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS). The secondary objective is to obtain an enhanced knowledge of surface angular and spectral properties that can be inferred from airborne directional radiance measurements.

II. Task Progress

a. MODIS-related Instrumental Research

After the first completion of the MAS 50-Channel Data Acquisition / Digitizer System (DAS), about 3 hours worth of data were collected on January 3, 1995. Jeff Myers at NASA Ames reported that all 50 channels appeared to be functioning, and the hardware performed well. Most of the IR channels were significantly cleaner than they were on the previous data system. The raw data look very strange, containing DC drift and digital gain / offset variations that must be removed during data post-processing. It is very tedious to examine all of these data immediately following flight using the newly developed "quick-look" system. Dave Augustine, in collaboration with Ames, continues to work on Quick-look display software for the 50-channel data system. This will allow the user to view the raw MAS data in either single channel, three channel simultaneous, or RGB composite modes; other options are an interactive stretch of the color tables (both upper and lower boundaries), tape manipulation (skip files, tape rewind, and position to selected scan) and custom color tables.

The performance of the MAS 50-channel instrument was further confirmed during Menzel's Houston experiment (January 5-20, 1995). The MAS and HIS (Highresolution Interferometer Sounder) were deployed together on NASA ER-2 aircraft for 8 missions (including ferry flights to and from Houston). Initial investigation of the 50-channel MAS data revealed very good performance in all four ports. In particular, for port four there was roughly a three to four times improvement over the NEΔTs achieved during TOGA-COARE. One important thing left for this new MAS 50-channel is the format and structure of a new level-1B HDF file format and contents. This must be carefully designed, and of course calibration results available for all 50 channels, before producing a useful archival level-1B product.

All CAR calibration data for MAST (Monterey Area Ship Tracks, June 1994) and SCAR-C (Smoke, Clouds, and Radiation - California, September 1994) has been analyzed and preliminary calibration coefficients were determined, based solely on the six-foot sphere Feb-94 source calibration. Tom Arnold compared these data to the CAR calibration data for the 48-inch hemisphere and showed excellent (<2%) agreement. Unfortunately, large changes in calibration (~20-30%) from the pre- to post-deployment (particularly for MAST) were observed. To account for these changes, the scan mirror was replaced by a freshly coated one and the telescope mirrors and accessible optics were all cleaned by Nita Walsh. Then, the CAR was recalibrated with the hemisphere and the recorded data were processed though appropriate calibration software. The resulting coefficients differed significantly from the post-SCAR-C calibration but, as hoped, they agreed well with the pre-MAST coefficients. Thus it is presumed that the 20-30% calibration change from pre- to post-MAST was likely due to degradation of the primary scan mirror surface. Max Strange made some modifications to the instrument panel box so that a new gain setting is temporarily held in memory and does not actually occur until the end of the active scan period. The CAR is now being calibrated for the June ARMCAS (Arctic Radiation Measurement in Column Atmosphere-surface System) field mission.

b. MODIS-related Data Processing and Algorithm Study

New 3.7 µm MAS channel images from the ASTEX experiment are now available on the World Wide Web. Jason Li has automated the procedure for producing the Mosaic GIF images from MAS-processed HDF data. The MAS 3.7 µm shortwave infrared channel is sensitive to cloud streaks generated by ship effluents. The Wild-Heerbrug RC-10 photographs, on the other hand, provide visual identification of the location of a ship for verification purposes. The combined RC-10 photograph and MAS 3.7 µm image contribute to a nice cover page for a paper that presents a summary of the MAST experiment (in preparation for *Bull. Amer. Meteor. Soc.*). To aid in the data analysis of each MAS (and others) mission, a considerable amount of time has been spent to construct an ER-2 Mission Summary booklet. The MAST experiment was selected to initialize the layout. The content of the MAST summary booklet includes a description of instrumentation contained on the ER-2 aircraft, a list of flight environmental conditions, mission summaries written by the ER-2 flight scientist on flight days, ground tracks flown by the ER-2, the MAS flight line summary for each flight, quick look images for an entire flight produced from MAS data, and summaries of the location and time of RC-10 camera photographs. This MAST summary booklet focuses primarily on MAS imagery, but also contains information on the RC-10 photography and availability of processed MAS data through the GSFC Distributed Active Archive Center (DAAC).

To aid in analyzing MAST data and validating our cloud retrievals, a flight track program was designed by Tom Arnold to plot both ER-2 and UW's C-131A flight tracks. For the C-131A flight tracks a dashed line is plotted for data when "in-cloud" (defined as FSSP liquid water content > 0.005 g m^{-3}) and a solid thin line is used for data when not "in-cloud." ER-2 tracks are plotted as a solid heavy line. Tracks are labeled with arrows every 10 minutes of flight and with a time code stamp at the start of each hour. To standardize our data format, Jason Li and Ward Meyer are restructuring all CAR data sets to adopt the HDF format.

An appreciable amount of time was spent on studying the effects of molecular (Rayleigh) scattering and water vapor absorption on cloud retrieval algorithm. The Rayleigh optical thickness at 0.664 µm is about 0.044 which is about two orders of magnitude smaller than the cloud optical thickness. Assuming a two-layer atmosphere with molecules above the cloud layer, Menghua Wang has simulated the upward reflectance at the top of the atmosphere for this air-cloud-ocean system. For the MAS 0.664 µm band, the upward reflectance at the top of the atmosphere (TOA) was computed for the cases of a cloud optical thickness τ_c = 2, 4, 6, 8, 10, and 12 and solar angles of 0° to 80° at step of 10°. Comparing the lookup library reflectance that was computed using a one-layer cloud layer with a flat ocean surface at the bottom, the %-difference of the reflectance is typically about 15% at $\tau_c = 2$ to less than 1% at $\tau_c = 12$. For the larger solar zenith angle θ_0 > 70°, the %-difference was even greater because of enhanced multiple scattering contribution from air molecules. From these results, we conclude that without a Rayleigh correction in our cloud retrievals, the cloud optical thickness would be overestimated. Therefore, it is very important to remove the Rayleigh contribution (especially for optically thin cloud layers). Steve Platnick worked independently in developing Rayleigh reflection and transmission matrices for use in his adding code to determine the effect of Rayleigh scattering on cloud retrievals. This provides us with an independent comparison.

It was further found by Menghua that water vapor transmission (t) can be approximated accurately using the analytical expression $t(\theta) = \exp(-[CW_0/\cos\theta]^a)$, where constant C and a are wavelength dependent, and W_0 is the column water vapor loading in (g cm^{-2}). This formula ignores the effects of atmospheric temperature and pressure in the water vapor transmission computation. Comparing these transmissions with the Lowtran-7 models for the 2.14 µm channel, the error is typically less than 0.5% for θ up to 60° for all Lowtran-7 model atmospheres. By implementing a water vapor correction (two-way transmission) into the cloud retrieval algorithm, the retrieved cloud effective particle radius and optical thickness for MAST on June 29, 1994 (Flight #7, scan line 1600 and 8000) were studied for various water vapor loadings. The corrected reflectances were compared with the lookup tables. The retrieved effective radius decreases with an increase in water vapor loading since the upward reflectance was increased. However, the retrieved effective particle radius inside the ship tracks was not sensitive to the water vapor loading.

In analyzing MAST data, Steve found that gradient search methods may not always be accurate for near-IR bands other than the 3.7 µm channel. When the optical thickness is relatively small (e.g., ≈ 6) there may be a few local minima which, in turn, can lead to multiple solutions for both the 1.6 and 2.2 µm bands at realistic radii. Further study of this problem is currently underway. Steve is also collaborating with the CERES Science Team at NASA Langley Research Center on providing a cloud retrieval code for use in their upcoming global AVHRR study. After completing the reflectance and emission libraries for the spectral bandpasses of AVHRR NOAA-9 and compared with previous NOAA-11 and 12 libraries, he discovered that the effective variance of the drop size distribution (v_{eff}) is an important parameter. More sensitivity studies are underway.

We are working on the first comprehensive paper describing the details of the MAS instrumentation and prospective science. The title of this paper is "Airborne scanning spectrometer for remote sensing of cloud, aerosol, water vapor and surface properties" and it will soon be submitted to the *Journal of Atmospheric and Oceanic Technology* for publication.

c. ARMCAS experiment

The ARMCAS (Arctic Radiation Measurements in Column Atmosphere-surface System) will be conducted over the Arctic ocean during the month of June 1995 as part of the MODIS atmospheric science team activity. This field experiment is funded jointly by NASA (OMTPE) and NSF to provide coordination of the NASA ER-2 and University of Washington C-131A aircraft, and a surface team (Code 923). A science plan for this experiment is in preparation and will be available for all scientists involved shortly.

d. MODIS-related Services

1. Meetings

1. Si-Chee Tsay attended the coordination meeting among NSF/ONR SHEBA, DOE/ARM NSA site, and NASA FIRE-III field programs, in conjunction with the AMS 75th Annual Meeting, Dallas, TX on 15-20 January 1995;

2. Si-Chee Tsay attended DOE/ARM NSA site Instrument Team Meeting, Reston, VA on February 1 and gave a talk on "Measuring surface bidirectional reflectance;"

3. Michael D. King attended the Ocean Color Calibration / Validation Workshop at the University of Miami on February 22-24, and gave a presentation on the EOS calibration and validation program;

4. Michael D. King attended the Science Working Group for the AM Platform (SWAMP) meeting in Greenbelt, MD on March 1, and gave a presentation on the EOS calibration and validation program, and short term budgetary and programmatic pressures on NASA;

4. Si-Chee Tsay, Steven E. Platnick and Menghua Wang attended a one-day workshop with the CERES group at NASA Langley on March 6 to discuss collaboration between MODIS and CERES modeling and retrieval efforts;

5. Michael D. King and Si-Chee Tsay attended the SCAR-B Science Team Meeting, in conjunction with AGU Chapman Conference on Biomass Burning and Global Change, in Williamsburg, VA on March 12-13;

6. Michael D. King attended the DOE / ARM Science Team Meeting, San Diego, CA on March 20-23 and presented a paper entitled "Earth Observing System (EOS): Science Objectives & Validation Plans."

2. Seminars

1. King, M. D., "Clouds, Radiation and Climate from EOS," Geophysical Fluid Dynamics Laboratory, Princeton, NJ, January 13, 1995.

III. Anticipated Activities During the Next Quarter

a. Continue to analyze MAS data obtained from the MAST field campaign and compare with in situ microphysics measurements;

b. Continue to study the implementation of atmospheric corrections in our cloud retrieval algorithm;

c. Continue to analyze FIRE-II Cirrus and ASTEX data gathered by the MAS and CLS, as well as theoretical studies, and prepare manuscripts for submission to journals;

d. Continue to analyze surface bidirectional reflectance measurements obtained during the Kuwait Oil Fire, LEADEX, ASTEX and SCAR-A experiments;

e. Attend CERES and MODIS Science Team meetings at LaRC (April 19-21) and GSFC (May 3-5), respectively;

f. Attend FIRE-III and SHEBA Science Team meetings at Baltimore (May 30-June 2).

g. Prepare and conduct the NASA / NSF ARMCAS field campaign as part of the MODIS research activities, in Fairbanks and Prudhoe Bay, Alaska during June 1995.

IV. Problems/Corrective Actions

No problems that we are aware of at this time.

V. Publications

1. King, M. D., D. D. Herring and D. J. Diner, 1995: The Earth Observing System (EOS): A space-based program for assessing mankind's impact on the global environment. *Opt. Photon. News*, **6**, 34–39.

2. King, M. D., and M. K. Hobish, 1995: Satellite instrumentation and imagery. *Encyclopedia of Climate and Weather*, Oxford University Press (in press).

3. King, M. D., S. C. Tsay and S. Platnick, 1995: In situ observations of the indirect effects of aerosol on clouds. *Dahlem Workshop on Aerosol Forcing of Climate*, R. J. Charlson and J. E. Heintzenberg, Eds., John Wiley and Sons (in press).

4. Gumley, L. E., and M. D. King, 1995: Remote sensing of flooding in the US upper midwest during the summer of 1993. *Bull. Amer. Meteor. Soc.* (in press).

5. Wielicki, B. A., R. D. Cess, M. D. King, D. A. Randall and E. F. Harrison, 1995: Mission to Planet Earth: Role of clouds and radiation in climate. *Bull. Amer. Meteor. Soc.* (in press).